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Aerospace Medicine

THERMAL INJURY

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Air Force Policy Directive (AFPD) 48-1, **Aerospace Medical Program**, emphasizes that ‘the ability of the Air Force to conduct effective and sustained combat operations depends largely on the physical and mental health of its personnel’ and directs that the Air Force Medical Services will focus on identifying and reducing the risk of illness and injury through appropriate surveillance, prevention and control programs and measures. This Air Force Pamphlet (AFPAM) supports AFPD 48-1 in the area of Thermal Injury prevention by providing background information and guidance to Commanders, supervisors and individuals at every level on environmental measurement, recognition and prevention of the signs and symptoms of Thermal Injury.

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Chapter 1

BACKGROUND

1.1. Introduction. AFPD 48-1 emphasizes that ‘the ability of the Air Force to conduct effective and sustained combat operations depends largely on the physical and mental health of its personnel.’ Moreover, it directs that the Air Force Medical Services will focus on identifying and reducing the risk of illness and injury through appropriate surveillance, prevention and control programs and measures. This AFPAM supports AFPD 48-1 in the area of thermal protection of USAF personnel by providing background information and direction to Commanders, supervisors and individuals on the measurement and prevention of thermal injury on USAF personnel.

1.2. Purpose. The Purpose of this AFPAM is to provide guidance in the prevention and treatment of thermal injury in USAF personnel.

1.3. Historical Perspective. History has demonstrated the difficulties of operating in hostile thermal environments. Heat exhaustion was noted as a serious problem during medical support operations to the 10th Air Force in India and Burma during WWII¹. Furthermore, recent deployed operations to the Middle East and the Balkans have emphasized the hostility and unpredictability of the thermal environment. The thermal stresses upon, and subsequent thermal strain experienced by, the war-fighter can have a detrimental effect upon mission success by degrading both individual and, ultimately, collective performance. Such risk in the training environment was highlighted by the recent deaths of recruits in the United Kingdom¹ and the US at Sandhurst and Lackland AFB respectively.

1.4. Basic Heat Exchange Principles. Thermal injury is caused by either a rise or fall in the body’s core temperature. Control of human body temperature can be simplified in the following heat balance equation:

$$\text{Heat storage} = \text{Heat Gained} - \text{Heat Lost}$$

1.4.1. Heat may be gained from that generated by exercise, the surrounding environment and equipment. Heat loss is mainly through sweating although a small amount is lost through conduction and convection. Excess heat gain over heat loss may result in the storage of heat in the body and vice versa, the result of which is a rise or fall in the body core temperature with the associated potential for injury.

1.4.2. Moreover, when individuals are wearing impermeable NBC clothing assemblies or protective clothing assemblies, personal fatigue and time to exhaustion are inversely related to the initial level of core body temperature and are directly related to the rate of heat storage¹.

1.4.3. Individual and collective risk of aircrew and ground crew error exists in thermal environmental extremes. Israeli research clearly demonstrated a significant increase in the risk of rotary aircrew errors associated with rising ambient temperatures². Furthermore, in the training environment, measures taken in the Israeli Defense Force since the 1950s have reduced the incidence of exertional heat stroke (EHS) and formed the basis for a proactive heat intolerance-screening program².

1. Gonzalez-Alonso et al ‘Influence of Body Temperature on the Development of Fatigue During Prolonged Exercise in the Heat’ *Journal of Applied Physiology* Vol 86 Mar 1999 pp. 1032-1039
2. Epstein et al ‘Exertional Heat Stroke - A Case Series’ *Med Sci Sport Exerc* 1999

1.5. Definitions. The following definitions are used in this AFPAM:

1.5.1. **Heat Illness** . Traditionally heat illness has been divided into *heat exhaustion* and *heat stroke*. In practice the division is difficult to define, thus, for the purpose of this AFPAM the term ‘Heat Illness’ is all embracing and applies to an individual who becomes incapacitated as the result of a rise in core body temperature.

1.5.2. **Cold Injury**. Cold environments pose a threat to the individual if they exceed the capacity of the body’s thermo-regulatory response mechanisms. The main hazards are *hypothermia* associated with a fall in the body’s core temperature and/or *tissue damage* that falls under the broad headings of freezing cold injury (FCI) and non-freezing cold injury (NFCI). For the purpose of this AFPAM the term ‘Cold Injury’ is all embracing and applies to an individual who becomes incapacitated as the result of a drop in core body temperature, FCI or NFCI.

Chapter 2

GENERAL HEALTH SUPPORT, PREVENTIVE MEASURES AND RISK FACTORS

2.1. Training, Exercise and Operations. During training, exercises and operations, Commanders must take into account general health support measures in hostile thermal environments that complement specific temperature observations, comprising:

- 2.1.1. Provision and management of appropriate work and rest schedules.
- 2.1.2. Training and information to all assigned personnel in the recognition of the signs and symptoms and prevention of heat illness and cold injury combined with the maintenance of personnel's general aerobic fitness.
- 2.1.3. Provision of appropriate fluid replacement in both hot and cold environments.
- 2.1.4. The associated implications of operating in a hot or cold environment while wearing impermeable clothing such as NBC warfare assemblies.
- 2.1.5. Where the tempo of operations permits, the importance of acclimatization measures.

2.2. Preventive Measures. The key to the prevention of thermal injury is an awareness of thermal risk factors by Commanders, supervisors and individuals at all levels. Any task involving physical exertion in a hot or cold climate and subsequent exposure to high or low ambient temperature should be considered a high-risk activity, particularly if NBC or impermeable protective clothing assemblies are worn. Specifically, the risk of casualties from work in heat or cold is dependent upon the environmental conditions, work rate and clothing worn. When there is a thermal casualty risk, it is the Commander's duty to ensure that resources are available to undertake an appropriate risk assessment. A combination of administrative and physical methods of risk management provides greater protection to a workforce than single measures alone³.

2.3. Acclimatization to Heat. The process of acclimatization is characterized by a series of physiological adjustments that occur when an individual is exposed to a hot climate. Acclimatization must be specific for the destination environment and produce beneficial physiological changes to the individual that minimize the risk of heat injury. Adaptation typically occurs during the first 10 to 14 days of heat exposure and the largest change occurs at days 3 to 5. A period of acclimatization is required for all personnel regardless of each individual's physical condition. An individual is considered acclimatized if he or she has undertaken regular exercise for longer than 10 days in the same environmental conditions as the proposed activity. However, adaptation is lost within a few weeks unless the exposure to heat is repeated regularly at intervals of four days or less. If exposure to the hot environment has followed a substantial period of travel or crossing time zones, the acclimatization time must be assumed to be longer than 10 days. In general, one extra day should be allowed for each time zone crossed. The effects and potential benefits of heat acclimatization are shown in the table below⁴:

3. Millican, Baker & Cook 'Controlling Heat Stress - Administrative versus physical control' *American Industrial Hygiene Association Journal* Vol 42(6) Jun 1981 pp. 411-416.

4. *Idem*

Table 2.1. Effects of Acclimatization to Heat.

Effects of acclimatization to heat	
Increase in:	Decrease in:
Work output	Heart rate
Endurance	Pulse pressure
Plasma volume	Basal oxygen consumption
Sweat production	Sweat electrolyte concentration
	Skin and core temperature

2.4. Individual Risk Factors for Heat Injury. There is wide variation in human tolerance to heat stress. Nevertheless, it is possible to identify factors that cause particular individuals to become heat casualties. The following personal factors must be considered when assessing individual heat injury risk:

- 2.4.1. Obesity.
- 2.4.2. Lack of physical fitness and/or lack of sleep.
- 2.4.3. Recent alcohol intake.
- 2.4.4. Concurrent mild illness e.g., diarrhea, viral illness, fever.
- 2.4.5. Dehydration.
- 2.4.6. Medication or illegal drugs.

2.5. Individual Risk Factors for Cold Injury. Systematic review of accidental cold injury has identified the following individual risk factors in a cold environment and must be considered⁵:

- 2.5.1. Alcohol.
- 2.5.2. Psychotropic medication.
- 2.5.3. Insufficient clothing.
- 2.5.4. Wetness from either the environment or sweat.
- 2.5.5. Lean body mass.
- 2.5.6. Physical exhaustion.
- 2.5.7. Concomitant illness.

2.6. Environmental Assessment and Determination of Thermal Injury Risk. The risk of thermal injury can be determined by an assessment of the thermal stress placed upon personnel as a function of the air temperature, wind speed and humidity. Measurement indices of these environmental parameters fall into 3 categories, according to their derivation and comprise:

5. Lloyd E, 'ABC of Sports Medicine: Temperature and Performance', *British Medical Journal* 1994; 309: 587-589.

2.6.1. Indices that measure physical heat exchange but ignore the human physiological response to thermal stress. Examples include the Index of Thermal Stress⁶ and the Heat Stress Index⁷.

2.6.2. Indices based upon empirical observations from physiological experiments including the WBGT Index⁸, the Wet Dry Index⁹, and the predicted 4 Hour Sweat Rate¹⁰ and the FITS^{11,12} Indices such as the Modified Discomfort Index (MDI) have been developed for the land environment and although these indices may be easier to calculate and administer they require further research¹³.

2.6.3. Indices based upon the subjective responses of individuals exposed to different thermal environments, such as the Effective Temperature Index¹⁴ and the Corrected Effective Temperature¹⁵. In sum, this group attempts to provide a measure of thermal comfort rather than thermal stress.

2.6.4. Moreover, numerous indices exist which are of use to the thermal physiologist in the laboratory but are of little practical value to the flight surgeon, bio-environmental engineer or occupational physician in the field due to their complexity or difficulty in obtaining subject body core temperature measurements. Thus, this AFPAM utilizes those indices that can be easily applied, measured and interpreted when conducting both deployed or home base operations; namely the WBGT Index, FITS and WCT Index.

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6. Lloyd E, 'ABC of Sports Medicine: Temperature and Performance', *British Medical Journal* 1994; 309: 587-589.
 7. Belding H S & Hatch T F, 1955.
 8. Yaglou C P & Minard D, 'Control of Heat Casualties at Military Training Centres' *American Medical Association Archives of Industrial Health* Vol 16 1957 pp. 302-316.
 9. Leithead & Lint, 1964.
 10. McArdle et al, 1947.
 11. Nunnley, S A & Stribley, R F 'Fighter Index of Thermal Stress (FITS): Guidance for Hot Weather Aircraft Operations' *Aviation, Space & Environmental Medicine* Vol 50 1979, pp.639-642.
 12. Nunnley, S A et al 'Heat Stress in Front and Rear Cockpits of F-4 Aircraft' *Aviation, Space & Environmental Medicine* Vol 52(5) May 1981 pp. 287-290.
 13. Moran & Pandolf 'Wet Bulb Globe Temperature - to what extent is GT essential?' *Aviation, Space & Environmental Medicine* Vol 70(7) Jul 1999 p. 720.
 14. Yaglou, 1927.
 15. Bedford, 1964.

Chapter 3

THERMAL INDICES

3.1. The WBGT Index¹⁶. Detailed analysis of the influence of the environment on thermal stress requires a knowledge of the following 4 basic parameters; air temperature; mean radiant temperature, air speed and absolute humidity. The WBGT Index combines the measurement of two derived parameters, natural wet bulb temperature (Tnwb) and the black globe temperature (Tbg) and, in some situations, the measurement of the basic parameter, air temperature (Tdb). The WBGT index can be determined using either the field apparatus described in the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limits Values (TLV) and Biological Exposure Indices (BEI) Handbook, the portable hand-held WBGT kit (NSN 6665-00-159-2218) or a suitable commercially available apparatus. The WBGT formulae are as follows¹⁷:

3.1.1. $WBGT = 0.7Tnwb + 0.2Tbg + 0.1Tdb$ C (Outdoors).

3.1.2. $WBGT = 0.7Tnwb + 0.3Tbg$ C (Absent Solar Load or Indoors).

(Where Tnwb = natural wet bulb, Tbg = black globe and Tdb = dry bulb temperatures)

3.1.3. Thermal stress indices that account for the thermal environment provide further guidance to Commanders against which they can judge the risk of injury to their subordinates against the mission requirements. Therefore, the measurement of the WBGT index must closely relate to the training or working conditions.

3.1.4. Base Bioenvironmental Engineering (BEE) personnel are usually responsible for WBGT measurement and must specify in local instructions where estimations are to be taken. Base weather personnel may perform additional measurements. The data collected is to be compared to reference values shown at Tables A2-1 and A2-2 at Attachment 2 and, when necessary, used to implement administrative and personnel procedures to directly reduce thermal strain and subsequent thermal stress at the work place.

3.1.5. BEE personnel should establish normal, expected and average WBGT index measurements for occupationally heat exposed personnel in indoor environments or confined spaces. When the forecast outside temperature reaches 85F as a daily high WBGT measurements are to be taken a minimum of 4 times, evenly spaced, during the hottest part of the day.

3.1.6. Thermal stress levels are to be displayed around the base by using a color-coded system, such as flags or boards as highlighted at Table A2-2 of Attachment 2. Consideration must be given to increasing the frequency of WBGT measurements in particularly hot environments.

3.2. FITS. The FITS was developed in the late 1970s¹⁸ to provide a measure of the thermal stress experienced by aircrew in fast jet aircraft with canopies and environmental control systems, engaged in combat sorties at low level altitude. The FITS is based upon the following formula:

16. American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limits Values (TLV) and Biological Exposure Indices (BEI) Handbook 1999.

17. ISO 7243: 1989 para 2, p2.

18. Nunnley S A & Stribley R F 'Fighter Index of Thermal Stress (FITS): Guidance for Hot Weather Aircraft Operations' *Aviation, Space & Environmental Medicine* Vol 50 1979, pp.639-642.

3.2.1. $(F) = 0.83T_{wb} + 0.35T_{db} + 5.08$

3.2.2. The calculated values assume an Aircrew Equipment Assembly (AEA) thermal insulation of 1.5-2.0 clo, roughly equivalent to light, summer AEA. Therefore, the index is not appropriate for cold weather, immersion suit or NBC assemblies. Nevertheless, in hot environments, the FITS provides a measure of thermal strain required to determine the risk of aircrew heat stress and injury, and minimizes the potential risk of error.

3.2.3. Meteorological staffs in conjunction with BEE personnel are to determine jointly the FITS zones shown at Table A3-1 of Attachment 3 based upon the WBGT measurement. Squadron Operations Flights then determine the zone applicability within the aircrew-working environment and display the appropriate warning color for aircrew. Aircrew have a responsibility to monitor their physical condition and not to exceed their capability to safely accomplish the mission. The following zone limits of exposure are recommendations only; Wings should develop additional restrictions if the mission requirements allow.

3.2.4. **FITS Caution Zone.** The following procedures should be implemented:

3.2.4.1. Be alert for symptoms of heat stress.

3.2.4.2. Drink plenty of non-caffeinated fluids.

3.2.4.3. Avoid exercise 4 hours prior to take off.

3.2.4.4. Limit ground operations time to 90 minutes outside an air-conditioned environment.

3.2.5. **FITS Danger zone.** In addition to the above procedures:

3.2.5.1. Minimum recovery time, landing time to next take off between flights is 2 hours.

3.2.5.2. Limit ground operations to 45 minutes for fighter/trainer aircraft types; time outside air-conditioned environment.

3.2.5.3. If possible, wait in a cool shaded area if the aircraft is not ready to fly.

3.2.5.4. Complete a maximum of 2 aircraft inspections, 2 exterior inspections on initial sorties and 1 exterior inspection on subsequent sorties for fighters and trainers.

3.2.5.5. Undergraduate Flying Training solo students are to complete 1 exterior aircraft inspection per sortie.

3.3. The WCT¹⁹. Cold injury prevention relies upon minimizing exposure and reducing heat loss using clothing. Operations in cold regions of the world expose personnel to the hazards of cold stress and consequent risk of hypothermia, FCI and NFI. On 1 Nov 01, Air Force Weather Units implemented the revised WCT Index Chart for 2001/2002 shown at Table A 4-1 of Attachment 4. Specifically the new calculation accounts for:

3.3.1. A calculated wind speed at an average height of five feet or the typical height of an adult human face based on readings from the national standard height of 33 feet, the typical height of an anemometer.

3.3.2. Basis on a human face model.

19. C A Nelson et al 'Review of the Federal Inter-agency Process Used to Select the New Wind Chill Temperature (WCT) Index, Nov 2001, Unpublished at present.

3.3.3. Modern heat transfer theory and heat loss from the body to the surroundings during cold and breezy or windy days.

3.3.4. Lowering the calm wind threshold to 3 mph.

3.3.5. A consistent standard for skin tissue thermal resistance.

3.3.6. Assume no impact from the sun (clear night sky); however, the WCT is to be further developed in 2002 to add calculations for sunlight and a variety of sky/cloud conditions.

3.4. BEE Personnel. BEE personnel remain responsible for the determination of the Wind Chill Index zones of risk and displaying colored flags or boards on base in order to minimize the risk of cold injury to personnel IAW the WCT.

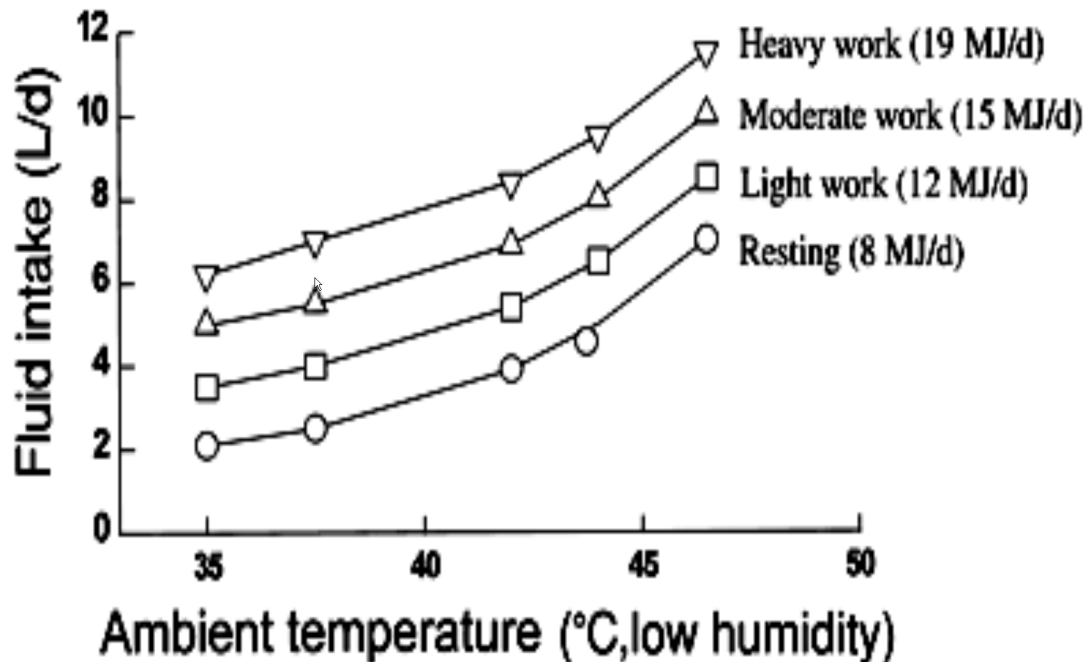
Chapter 4

THE ADMINISTRATIVE APPLICATION OF THE WBGT, FITS AND WCT INDICES.

4.1. Fluid Replacement. Water is the key component of sweat that enables heat loss to occur. Therefore it is essential to maintain fluid intake to meet losses secondary to evaporation and maintain hydration. All water referred to in this AFPAM is to be cool, potable and from a guaranteed safe source.

4.1.1. Thirst is an unreliable guide to the level of hydration in either a hot or cold environment. Personnel are to drink adequate water before, during and after high thermal risk activities. Urine color is a reliable indicator of an individual's hydration status. Personnel exposed to either extreme of hot or cold environments are to be instructed to drink sufficient water that their urine remains colorless. The risks of over hydration and potential electrolyte imbalance are to be emphasized to all personnel. Examples of fluid intake for given workloads are displayed below:

Figure 4.1. Approximate fluid intake against ambient temperature during heavy, moderate, light work and rest (after Sawka and Montain, 2000)



NOTE: Michael Sawka & Scott J Montain, 'Fluid and Electrolyte Supplementation for Exercise Heat Stress', *American Journal of Clinical Nutrition*, Vol 72, No 2, p566

4.2. Fluid Composition, Sodium Intake and Dietary Supplementation. Replacement fluid composition remains the subject of academic debate and research. The Military Committee on Nutritional Research (1994²⁰) considered electrolyte replacement, endurance and performance. In summary, there was little direct evidence that electrolyte supplementation was beneficial except in a small proportion of endurance athletes. However, the low concentrations of electrolytes found in most fluid replacement bev-

20. David R Lamb 'Fluid Replacement and Heat Stress': Committee on Military Nutrition Research 1994, pp 27-29

erages can enhance palatability and thus serve to encourage fluid consumption. Notwithstanding this potential benefit, the only study to examine high sodium intake, both as a supplement to diet in food and electrolyte drinks, during heat acclimatization found detrimental cardiovascular and performance effects. Under-hydration was postulated as a potential mechanism since 1 liter of water must be consumed for each 5g of sodium chloride added to the diet²¹. Personnel are to be encouraged to maintain a normal diet, with supplemental salt to taste and must maintain a regular intake of water. Palatability of fluids may be enhanced by the addition of commercial electrolyte powders IAW AFMOA/CC policy²².

4.3. Workload and Fluid Intake in Hot Environments. Guidelines for work/rest schedules and fluid intake in the WBGT precaution zones for both acclimatized and un-acclimatized personnel in a hot environment are shown at Tables A5-1 and A5-2 of Attachment 5 respectively. Tables A6-1 and A6-2 of Attachment 6 provide a broad description of advisory work/rest schedules against WBGT index and a broad guide to the determination of workload intensity respectively. Line managers are to ensure that all personnel under their supervision are aware of these limitations.

4.4. Workload and Fluid Intake in Cold Environments. In cold environments the principle routes of fluid loss and subsequent deficit are cold induced diuresis, respiratory water loss, cold weather clothing, and the metabolic cost of movement and reduced fluid intake. Personnel should be encouraged to maintain fluid intake in accordance with the un-acclimatized recommendations at Tables A5-1 and A5-2 at Attachment 5. Theoretically, glycerol solutions may be appropriate fluid replacement in cold environments to delay gastric emptying and promote fluid absorption, however, this area requires further study. Personnel are to be encouraged to eat a normal diet, incorporating moderate carbohydrate and fat intake.

4.5. Precautionary Measures During Exercise in the Heat. The following general precautionary measures are to be applied when exercising in heat:

4.5.1. Clothing should be lightweight, loose fitting and preferably natural fiber. Dress and equipment increase the risk of heat illness by increasing workload and by reducing the body area available for the evaporation of sweat. In hot environments, loose fitting clothing is to be worn, particularly at the neck and wrists to allow air circulation. Furthermore, appropriate headgear is to be worn, in addition to the use of sun block to prevent sunburn.

4.5.2. When Battle Dress Uniform (BDU) is required for a particular activity, the use of BDU Hot Weather is to be mandated and enforced when a yellow flag or higher WBGT heat condition is expected for the day. The wearing of helmets and combat armor significantly increases heat stress during strenuous activity. Five degrees F is to be added to the WBGT index if individuals are wearing combat armor.

4.5.3. During endurance exercise small quantities of fluid should be drunk at frequent intervals and water sprayed on the skin at every opportunity.

4.5.4. The use of sweat inhibiting deodorants should be avoided.

4.5.5. Personnel should not exercise in the heat immediately after a glucose or high carbohydrate meal due to the diversion of blood from the skin to the gastrointestinal tract.

21. Dasler et al, 1973.

22. AFMOA/CC Policy Memorandum 'Role of Sports Drinks in the Prevention of Dehydration and Heat Illness' dated 23 August 2001.

4.5.6. Endurance events should be cancelled if the WBGT index exceeds 82F.

4.6. Specialist Occupations in a Hot Environment . When individuals are working in ground crew ensemble, fire fighting gear or other similar restrictive or impermeable clothing, BEE personnel are to arrange remote onsite or workplace measurement of the WBGT index. For these specialist-clothing ensembles 10 degrees F is to be added to the WBGT measurement before applying the work schedule guidelines at Tables A5-1 and A5-2 of Attachment 5. A further 5 degrees WBGT should be added if individuals are wearing combat armor.

4.7. Cold Environment Considerations. Cold impinges on the safety of flight operations by a variety of mechanisms comprising:

- 4.7.1. Exposure of arms and hands with subsequent reduction in sensation and manual dexterity.
- 4.7.2. Discomfort and subsequent distraction.
- 4.7.3. Limitation of movement and duties while wearing bulky protective clothing.
- 4.7.4. Contact with freezing metal components and risk of FCI.
- 4.7.5. Dehydration.
- 4.7.6. Sleep deprivation is associated with higher sensations of cold and shivering²³.

4.8. Cold Exposure Reduction. Advisory work/rest schedules and practices in a cold environment are shown at Table A4-2 of Attachment 4²⁴. Moreover, the following may reduce cold exposure:

- 4.8.1. Elimination of non-essential outdoor tasks.
- 4.8.2. Where possible, performing tasks indoors.
- 4.8.3. Provision of temporary shelter for essential outdoors work, preferably heated.
- 4.8.4. Increasing the number of personnel allocated to a task and operating a rotational duty system.
- 4.8.5. Layered protective clothing systems are available to both aircrew and ground crew.

4.9. NBC Operations and Uncompensable Heat Stress (UCHS). NBC or impermeable protective clothing ensembles significantly increase the thermal load placed upon the individual that resulting in uncompensable heat stress. Further guidance on work/rest schedules and the importance of fluid balance in a NBC environment is available in Air Force Manual 32-4005, **Personnel Protection and Attack Actions**. Further, a variety of physiological factors may minimize the subsequent thermal strain experienced by individuals in MOPP ensembles. Following laboratory exercise experiments conducted in the Canadian NBC assembly, Cheung and McLennan²⁵ concluded that:

- 4.9.1. High aerobic fitness from long-term training and habitual exercise is of significant benefit.

23. Savourey G & Bittel J, 'Cold Thermoregulatory Changes Induced by Sleep Deprivation in Men', *European Journal of Applied Physiology & Occupational Physiology*, 69 (Vol 3) 1994; pp 216-220.

24. Derived from USARIEM Technical Note No TN/02-2 'Sustaining Health and Pperformance in Cold Weather Operations' October 2001

25. Cheung SS & McLellan TM, 'Heat Acclimatization, Aerobic Fitness & Hydration Effects on Tolerance during Uncompensable Heat Stress', *Journal of Applied Physiology*, Vol 84(5) May 1998, pp1731-1739

4.9.2. When fluid replacement is provided, heat acclimation does not provide significant benefit regardless of fitness status. Fluid replacement may, therefore, be an effective substitute for a heat-acclimation program.

4.9.3. The magnitude of improvements in physiological strain with heat acclimation is greater in those subjects with high aerobic fitness, but the improvements are still insufficient to improve exercise-heat tolerance.

4.9.4. Mild hypo-hydration of 2-3% of body mass results in significant performance impairment, regardless of fitness or heat acclimation status.

4.10. Training and Education. Personnel assigned to hot or cold weather operations should receive thorough training in the bio-medical problems of heat and cold, with continuation training annually. Training should include the subtle psychomotor signs of thermal injury. Suggested topics include the following:

4.10.1. Climate. Local weather conditions, heat stress index concepts and warnings, wind-chill concepts and warnings.

4.10.2. Heat Illness. Fluid replacement, work/rest schedules, signs and symptoms, first aid treatment.

4.10.3. Cold Injury. Signs and symptoms of freezing and non-freezing cold injuries, human performance in the cold, psychomotor effects, fluid replacement.

4.10.4. Protective Clothing Systems. Principles of use, design, proper wear and maintenance, risk of wet clothing, associated hazards of protective clothing systems including reduced mobility, impaired hearing, visual fields and generation of static electricity.

4.10.5. NBC Operations and Heat Stress in both hot and cold environments.

Chapter 5

FIRST AID AND EMERGENCY TREATMENT GUIDANCE FOR HEAT & COLD INJURY

5.1. Heat Illness. Recognition of heat illness is the key principle in treatment and management. In general, any individual experiencing the following signs or symptoms during physical activity in a hot environment or while wearing protective clothing should be presumed to be suffering from heat illness:

- 5.1.1. Dizziness or confusion.
- 5.1.2. Nausea or vomiting.
- 5.1.3. Staggering.
- 5.1.4. Disturbed vision.
- 5.1.5. Confusion, collapse or loss of consciousness.

5.2. Heatstroke. Heatstroke develops when the body is unable to dissipate excess heat under various combinations of high environmental temperature, high humidity, lack of wind, vigorous activity, heat retaining clothing, and dehydration. Early symptoms include excessive sweating, headache, nausea, dizziness, hyperventilation, and disturbance of consciousness. Consciousness may be lost or clouded and there may be hallucinations. There may be muscle twitching or convulsions and loss of control of the body sphincters. In severe cases there may be deep coma with pinpoint pupils and shock with tachycardia. Tachypnoea is often present and breathing may become difficult and vomit subsequently inhaled. The patient feels warm or hot and has a high core temperature usually in excess of 103F. Sweating may or may not be present. The diagnosis depends upon a high index of suspicion.

5.2.1. Treatment of Heatstroke. Heatstroke victims are in danger of developing irreversible damage of the brain, kidneys, liver, and adrenal glands with subsequent death. Disseminated intra-vascular coagulation may occur. Treatment should be started as early as possible. Unnecessary cooling is safer than waiting for a definite diagnosis. On suspicion of heat stroke the following guidelines may be applied:

- 5.2.1.1. Lie the patient flat and raise the legs.
- 5.2.1.2. Cool by removing clothing, spraying with warm or tepid water, and fanning with warm air. Do NOT use ice baths, ice packs, cold sponging, or blowing cold air; the resulting cold stimulus may cause vasoconstriction, reduce heat loss, trigger shivering and increase heat production.
- 5.2.1.3. Re-hydrate with sodium rich fluid such as 0.9% saline. Several liters may be required to restore or maintain blood pressure. Intravenous bicarbonate will be needed to counteract the metabolic acidosis, however, this is best achieved in hospital once a measurement of acid/base status has been completed. Repeated doses of hydrocortisone 100 mg intravenously may be necessary if the blood pressure is falling. Transfer to a hospital intensive therapy unit.

5.3. Heat Syncope, Heat Exhaustion and Heat Cramps. Heat exhaustion is caused by excessive exposure to heat and the depletion of body fluids. Victims sweat profusely and may shiver and have goose bumps. Weakness, nausea, dizziness, headache, poor judgment, rapid pulse, and a normal or slightly elevated body temperature are present. Heat cramps occur in healthy individuals during or following strenuous physical activity. Muscles, oftentimes those in the calf, cramp and produce severe pain. Fainting from

the heat is referred to as heat syncope. Treatment includes rest in a cool, shaded environment and fluid replacement. Cramped muscles should be stretched or massaged.

5.4. Sunburn. Unprotected exposure to sun can cause sunburn, accelerate skin aging, may cause drug photosensitization and depress skin immune responses. Sunburn also increases the risks of skin cancer; basal and squamous cell carcinomas on exposed areas and melanomas anywhere on the body. Altitude and reflective surfaces such as fresh ice, snow, sand, metal, concrete and wind increase the risk and severity of sunburn.

5.4.1. Sunburn Prevention and Treatment. Clothing and sunscreens according to skin type can prevent sunburn. Sunscreens are to protect against ultraviolet (UV) A and UV B and provide a minimum sun protective factor of 15. The table below outlines sunburn treatment guidelines:

Table 5.1. Sunburn Treatment Guidelines.

Mild sunburn	Severe sunburn (blistering)
Avoid further exposure Cool soak-tap water Emollients Aspirin and other non-steroidal anti-inflammatory drugs Topical steroids	As for mild sunburn plus: Prednisolone oral 60 mg/day, tapering in one week Protect bullae if intact Admit to hospital

5.5. Cold Injury. If body heat loss exceeds heat production then hypothermia will develop. The condition is defined as occurring when the body's core temperature falls to 95 F or below. Recognizing the early signs and symptoms of hypothermia is the key to treatment and management. These include:

- 5.5.1. Profound shivering.
- 5.5.2. Slurred speech.
- 5.5.3. Psychological symptoms including aggressive or withdrawn behavior.
- 5.5.4. Progressive reduction in the shivering response and loss of consciousness.

5.6. Hypothermia . Hypothermia is defined as a core temperature below 95°F and develops as the rate of heat loss exceeds heat production. Three types of hypothermia can be distinguished, based upon the mechanism of cold exposure comprising²⁶:

- 5.6.1. **Immersion .** Very severe cold stress occurs, for example, following ejection into water.
- 5.6.2. **Exhaustion.** Less severe cold stress, most frequently following a combination of wind and wet exposure with moderately low temperatures.
- 5.6.3. **Urban.** Cold is relatively mild and prolonged. Most common in the elderly or malnourished, this condition may be seen in Peace Support or Humanitarian operations.
- 5.6.4. **Diagnosis of Hypothermia.** In a cold environment, the possibility of hypothermia should always be suspected. Early symptoms comprise changes in behavior followed by uncoordinated

26. Lloyd E 'ABC of Sports Medicine: Temperature and Performance I': Cold, *British Medical Journal* 1994; 309: 531-534.

movement, staggering, dysarthria and subsequent clouding and loss of consciousness (**G**rumble, **M**umble, **F**umble, and **S**tumble) with an eventual fall in heart and respiratory rate with death as the final outcome. It should be noted that similar symptoms occur in hyperthermia, exhaustion, and hypoglycemia. Measuring the core temperature, usually rectally, aids accurate diagnosis. However, low reading thermometers may not be readily available where casualties occur thus, for practical purposes, an individual should be treated as a cold casualty if the body feels "as cold as marble," particularly if the armpit is profoundly cold.

5.6.5. Pre-Hospital Management of Hypothermia. In all three preceding situations, removing the casualty from the cold environment prevents further heat loss. Movement must be gentle in order to avoid triggering cardiac arrest. Until the casualty is in shelter wet clothes should not be removed. Layers of insulating material should be placed on top of the casualty's clothing, including the head, and covered with a layer that is water and wind proof. Foil blankets are often recommended, but are no more effective than a similar thickness of very much cheaper plastic. These measures will probably be sufficient in immersion hypothermia. If available, airway warming, through the inhalation of warmed moist air, should be used. This treatment is of particular value in hypothermia secondary to exhaustion where it can prevent the occurrence of fatal cardiovascular collapse during re-warming. With urban hypothermia no additional heat, either surface or central, should be supplied before admission to hospital, as this may precipitate fatal pulmonary or cerebral edema or both by reversing inter-compartmental fluid shifts.

5.6.6. Resuscitation after Hypothermia. Respiratory obstruction should be cleared and, if necessary, expired air ventilation started using the same criteria and rate as in normothermia. Cardiopulmonary resuscitation, at the same rate as in normothermia, should be started if indicated. Casualties totally submerged in very cold water, especially those who are young, have been known to recover even after submersion of up to one hour. Resuscitation must start immediately on rescue. The indications for commencing cardio-pulmonary resuscitation comprise:

5.6.6.1. No carotid pulse is detectable for at least one minute OR cardiac arrest is observed; that is, the pulse disappears or there is a reasonable chance that cardiac arrest occurred within the previous two hours.

5.6.6.2. There should be a reasonable expectation that effective cardiopulmonary resuscitation can be continued, with only brief periods of interruption for movement, until the casualty can be transported to hospital and advanced life support can be provided.

5.7. Freezing and Non-Freezing Cold Injury. As skin temperature approaches 30 F, intense vasoconstriction of peripheral blood vessels takes place with the potential for freezing of tissues and subsequent frostbite (FCI). Moreover, prolonged contact with water or wet clothing in the temperature range of 53 F can result in NFICI, a condition where the peripheral nerves de-myelinate with resultant swelling, numbness and blanching followed some time later by intense pain and hyperemia in the affected body area. The following freezing cold injuries are described:

5.7.1. Frostbite. Frostbite is a localized lesion caused by freezing, usually affecting the feet, hands, ears, nose, and cheeks. The cornea has been affected in individuals not protected by goggles. Penile freezing can occur during exercise in tight or inadequate clothing or from direct contact with a metal zipper. Restricted peripheral circulation secondary to tight shoes or boots can increase the risk of frostbite as does dehydration, fatigue and exposure at altitude. In frostbite the tissues are hard, insensitive, and white or mottled. No attempt should be made to thaw frostbite if there is any chance of the

affected area becoming re-frozen. The freeze-thaw-re-freeze cycle causes greater damage than continuous freezing. It is safer to walk on frozen feet even for 72 hours.

5.7.2. Frostnip. In frostnip painful exposed skin blanches and loses sensation but remains pliable. The affected area should be warmed by placing it in the armpit or under clothing. Tingling is followed by hyperemia and within a few minutes sensation is restored and normal activity can be resumed.

5.7.3. Treatment. Re-warming should be carried out in a hot whirlpool bath, with gradual spontaneous rewarming as a second option. Beating, rubbing with snow, or rewarming with excessive heat can produce disastrous loss of tissue. Since damage from frostbite is usually more superficial than first suspected, debridement or amputation should be delayed for up to 90 days till mummification and demarcation are complete.

After recovery the sufferer can return to full activities with limitations imposed by the degree of any tissue loss.

5.7.4. NFIC. NFIC is characterized by tissue damage following prolonged exposure to temperatures above freezing, classically in the region of 59F. The following clinical presentations are identified:

5.7.4.1. Trench foot. Trench foot is the common title for non-freezing cold injury; others include immersion injury, paddy foot, tropical immersion foot and peripheral vasoneuropathy after chilling. Peripheral nerve de-myelination with potential muscle necrosis and atrophy develops over a long period of time as the affected body part is exposed to cold temperatures of around 60F. Although the term 'trench foot' suggests that the lower limbs are the most common site for NFIC, any body part may be affected; for example the buttocks may be injured when exposed to cold water or continuous surface contact while in a dinghy. Furthermore, prolonged walking on boggy ground or sweating in impervious boots may create similar cold and wet conditions. As in frostbite, damage is more likely if the casualty is also suffering from fatigue, dehydration, immobility, or wearing tight footwear. The feet are initially cold and numb, giving the sensation of "walking on cotton wool" and in combination with joint stiffness, the casualty walks with legs apart in order to maintain balance. Initial examination reveals feet that are cold, swollen, and blotchy pink-purple or blanched.

5.7.4.2. Treatment. Remove the person from the cold environment and allow the affected body part to rewarm spontaneously. After rewarming, the feet become hyperemic, hot, and red with paraesthesia or pain, often similar to electric shocks. These symptoms may be severe and last for several weeks, especially on weight bearing. Severe cases produce bleeding into the skin, ulceration, and blistering that may progress to gangrene. Consequent to nerve and other tissue damage, there is likely to be persistent or permanent hypersensitivity to cold with anesthesia or hyperaesthesia or problems with the bony structure of the feet.

5.8. Other Effects of Cold. Further to FCI and NFIC the following may also be seen in a cold environment:

5.8.1. Raynaud's Disease/Syndrome. Cold at a severity that does not affect normal people may cause severe arterial vasoconstriction, most commonly affecting the fingers, in individuals with Raynaud's Syndrome. In severe cases this may lead to digital ulceration and tissue loss. Protection from the cold by suitable clothing, gloves and shoes is usually sufficient however chemical hand warmers may be necessary. Individuals with Raynaud's are strongly advised not to smoke.

5.8.2. **Muscle injury.** Muscle and tendon tears may occur when a person is cold, since muscle action is inefficient and may be uncoordinated in concert with joint stiffness. An active warm up, sufficiently energetic and prolonged to ensure that the whole body is warm is an effective means for reducing the risk of injury and enhancing performance.

5.8.3. **Shivering.** Cold causes shivering that can produce a performance deficit in manual skills that require steadiness.

5.8.4. **Reduced Manual Dexterity.** The fingers are much less sensitive in the cold with subsequent loss of manual dexterity. Cold impairs coordination, reduces visual acuity, general alertness and slows reflexes. Individuals are prone to making mistakes in the cold and may misinterpret sights or sounds. Prolonged hypoxia or exposure to cold can cause hallucinations, particularly at altitude.

Chapter 6

SUMMARY

6.1. Summary. In summary, this pamphlet provides guidance for the prevention of thermal illness secondary to heat or cold exposure. Thermal illness may follow a rise or fall in body core temperature that is not compensated by the individual's thermo-regulatory system. Further, exposure of the extremities or bare skin to cold air or water may result in tissue damage and subsequent cold injury. The fundamental approach to be taken by Commanders is one of risk assessment and management.

6.2. Commander's Summary. Commanders should make every effort to protect personnel under their command from the adverse effects of the environment, allowing for the operational imperative, in order to maximize mission efficiency. Furthermore, the additional stresses placed upon individuals when operating in NBC equipment in a thermally hostile environment, should also be considered.

6.3. Comprehensive Approach. Although medical personnel have an active input in the prevention and treatment of thermal casualties, the multi-disciplinary approach of utilizing BEE, Public Health, Weather and Ops personnel in establishing and monitoring the thermal environment provides a comprehensive assessment of risk to personnel. Moreover, the overall approach to thermal injury prevention and risk management, in equal measure, involves administrative techniques as well as physical. Thus, this document provides guidance to Commands on thermal measurement techniques, assessment tools, work and rest schedules and basic medical treatment guidelines.

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Surgeon General

Attachment 1**GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION*****References***

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Abbreviations and Acronyms

ACGIH—American Conference of Governmental Industrial Hygienists

AEA—Aircrew Equipment Assembly

BDU—Battle Dress Uniform

BEE—Bioenvironmental Engineer

BEI—Biological Exposure Indices

EHS—Exertional Heat Stroke

FCI—Freezing Cold Injury

FITS—Fighter Index of Thermal Stress

ISO—International Organization for Standardization

MOPP—Mission-oriented protective posture

MDI—Modified Discomfort Index

NBC—Nuclear, Biological, and Chemical

NFCI—Non Freezing Cold Injury

TLV—Threshold Limit Values

Tbg—Temperature: Black Globe

Tdb—Temperature: Dry Bulb

Tnwb—Temperature: Natural Wet Bulb

UCHS—Uncompensable Heat Stress

USARIEM—US Army Research Institute of Environmental Medicine

UV—Ultra-violet Radiation

WBGT Index—Wet Bulb Globe Thermometer Index

WCT—Wind Chill Temperature Index

Attachment 2

WET BULB GLOBE THERMOMETER TABLES

Table A2.1. Wet Bulb Globe Thermometer (WBGT) Index Reference Values.

Metabolic Rate Class	Metabolic Rate (M)		Reference Value of WBGT			
	Related to a unit skin surface area W/m ²	Total (for a mean skin surface area of 1.8m ²) W	Person acclimatized to heat (F)		Person NOT acclimatized to heat (F)	
0 (Resting)	M<65	M<117	91.4		89.6	
1	65<M<130	117<M<234	86		84.2	
2	130<M<200	234<M<360	82.4		79	
3	200<M<260	360<M<468	No Sensible Air Movement 77	Sensible Air Movement 79	No Sensible Air Movement 72	Sensible Air Movement 73.4
4	M>260	M>468	73.4	77	64.4	68

Table A2.2. Wet Bulb Globe Thermometer (WBGT) Stages, Temperature Ranges and Flag Colours.

STAGE	Temperature Range	Flag Color
1	78 - 81.9 F WBGT	No Flag Required
2	82 - 84.9 F WBGT	Green
3	85 - 87.9 F WBGT	Yellow
4	88 - 89.9 F WBGT	Red
5	90 F WBGT and higher	Black

Attachment 3

**FIGHTER INDEX THERMAL STRESS (FITS) REFERENCE VALUES
AND ADVISORY FLAG COLORS**

Table A3.1. Fighter Index of Thermal Stress (FITS) Reference Values and Flag Colors.

Dry Bulb Temperature	Zone	Dew Point Temperature								
(F)		30	40	50	60	70	80	90	100	>110
70		70	73	76	81	86	X	X	X	X
75		74	77	80	84	89	X	X	X	X
80	NORMAL	77	80	83	87	92	98	X	X	X
85		81	83	86	90	95	101	X	X	X
90		84	87	90	93	98	104	110	X	X
95		88	90	93	96	101	108	112	X	X
100		91	93	96	99	104	109	115	122	X
105	CAUTION	94	96	99	102	107	112	118	124	X
110		97	99	102	105	109	114	120	126	133
115		100	102	105	109	112	117	123	129	136
120	DANGER	104	105	108	111	115	120	125	131	138

Attachment 4

WIND CHILL TEMPERATURE INDEX REFERENCE VALUES AND ADVISORY FLAG COLORS

Table A4.1. Wind Chill Index and Flag Colors.

WINDSPEED		TEMPERATURE (F)								
CALM	CALM	40	35	30	25	20	15	10	5	0
KNOTS	MPH	EQUIVALENT CHILL TEMPERATURE								
3 to 6	5	35	30	25	20	15	10	5	0	-5
7 to 10	10	30	20	15	10	5	0	-10	-15	-20
11 to 15	15	25	15	10	0	-5	-10	-20	-25	-30
16 to 19	20	20	10	5	0	-10	-15	-25	-30	-35
20 to 23	25	15	10	0	-5	-15	-20	-30	-35	-45
24 to 28	30	10	5	0	-10	-20	-25	-30	-40	-50
29 to 32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33 to 36	40	10	0	-5	-15	-20	-30	-35	-45	-55
		CAUTION					NO FLY			

Cold Environment Guidelines

Table A4.2. Working Practice Guidance in Cold Environment.

Wind Chill Condition	Required Precautions and Hourly Work/Warming Cycle ^a
Standard	Wear gloves, do not perform work for more than 10 minutes, and cover metal handles and bars with thermal insulation.
Moderate	Follow Standard precautions, no outdoor operations with water (vehicle/aircraft washing), wear gloves and total body protection, avoid heavy sweating, change wet clothes immediately, implement the 'buddy' system. 50 MINUTES WORK/20 MINUTES WARMING
Caution	Follow both Standard and Moderate precautions, wear mittens not gloves. 40 MINUTES WORK/20 MINUTES WARMING
Danger	Follow Standard through Caution actions. 30 MINUTES WORK/30 MINUTES WARMING
Extreme	MISSION CRITICAL WORK ONLY ^b

a. Warming must be in an indoor, heated environment.

b. The Unit Commander will determine which tasks are mission critical.

Attachment 5

TRAINING GUIDELINES FOR ACCLIMATIZED AND UN-ACCLIMATIZED PERSONNEL WEARING HOT WEATHER BDU

Table A5.1. Training Guidelines for Average Acclimatized Airmen Wearing BDU, Hot Weather.

Heat Cat/Flag Color	WBGT (F)	EASY WORK		MODERATE WORK		HARD WORK	
		Work Rest Cycle	Water Intake Qt/hr	Work Rest Cycle	Water Intake Qt/hr	Work Rest Cycle	Water Intake Qt/hr
1	78 - 81.9	No Limit	0.5	No Limit	0.75	40/20 min	0.75
2	82 - 84.9	No Limit	0.5	50/10 min	0.75	30/30 min	1.0
3	85 - 87.9	No Limit	0.75	40/20 min	0.75	30/30 min	1.0
4	88 - 89.9	No Limit	0.75	30/30 min	0.75	20/40 min	1.0
5	> 90	50/10 min	1.0	20/40 min	1.0	10/50	1.0

Table A5.2. Training Guidelines for Average Unacclimatized Airmen Wearing BDU, Hot Weather.

Heat Cat / Flag Color	WBGT (F)	EASY WORK		MODERATE WORK		HARD WORK	
		Work Rest Cycle	Water Intak Qt/hr ^a	Work ^b Rest ^c Cycle	Water Intake Qt/hr	Work Rest Cycle	Water Intake Qt/hr
1	78 - 81.9	No Limit	0.5	50/10 min	0.75	30/30 min	0.75
2	82 - 84.9	No Limit	0.5	40/20 min	0.75	30/30 min	1.0
3	85 - 87.9	No Limit	0.75	30/30 min	0.75	20/40 min	1.0
4	88 - 89.9	50/10 min	0.75	20/40 min	0.75	10/50 min	1.0
5	> 90	40/20 min	1.0	10/50 min	1.0	Not allowed	Not applicable

a. For all 3 work rates, individual water requirement may vary by +/- 0.25 qt/hr.

b. When performing work/exercise with ground crew ensemble, fire-fighting gear or other similar restrictive or impermeable clothing arrangements should be made for remote site measurement of the WBGT and 10 degrees F added to the measurement before using tables 3 or 4. Add 15 degree WBGT if also wearing combat armour.

c. Rest means minimal physical activity, i.e. sitting or standing, accomplished in the shade if possible.

Attachment 6

PERMISSIBLE HEAT EXPOSURES AND WORKLOAD DETERMINATION

Table A6.1. Permissible Heat Exposures (Values in F WBGT).

WORK AND REST REGIME PER HOUR	WORK LOAD		
	LIGHT	MODERATE	HEAVY
Continuous Work	86	80	77
75% Work / 25% Rest	87	82	78
50% Work / 50% Rest	89	85	82
25% Work / 75% Rest	90	88	86

Table A6.2. Guide to Determination of Workload.

EASY WORK	MODERATE WORK	HARD WORK
-- Walking on hard surface @ 2.5 mph with ≤ 30 lb load	-- Walking on hard surface @ 3.5 mph with < 40 lb load	-- Walking on hard surface @ 3.5 mph with ≥ 40 lb load
-- Weapon Maintenance	-- Walking loose sand @ 2.5 mph with no load	-- Walking on loose sand @ 2.5 mph with load
-- Manual of Arms	-- Patrolling	
-- Marksmanship Training	-- Low crawl, high crawl	
-- Drill and Ceremony	-- Defensive position construction	
	-- Field Assaults	